

**2005 Summer Meeting/Conference of the Transportation Research  
Board ADC40 (A1F04) Noise & Vibration Committee**

**Presentations – Underwater Noise**

**Washington State Ferries' Experience with  
Bubble Curtains: Purpose, Hardware, and Use**

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for  
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# Washington State Ferries Bubble Curtain Projects

Mukilteo Tower Repair ('03)

Shaw Terminal Preservation ('03-'04)

Port Townsend Terminal Preservation ('04)

Friday Harbor Terminal Preservation ('04-'05)

## Other Bubble Curtain Projects

Glacier Northwest/Maury Island ('03)



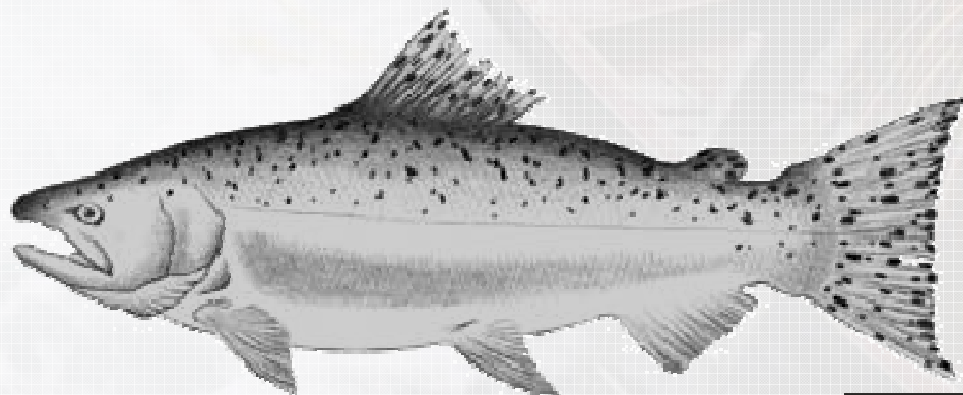


# Purpose

***To reduce the damaging effects to fish of sound pressures resulting from impact pile driving.***

Incompressible water is an excellent transmitter of sound pressures.

Compressible air bubbles absorb and attenuate the transmission of sound pressures through water.



# MUKILTEO TOWER REPAIR: Bubble Curtain Specifications

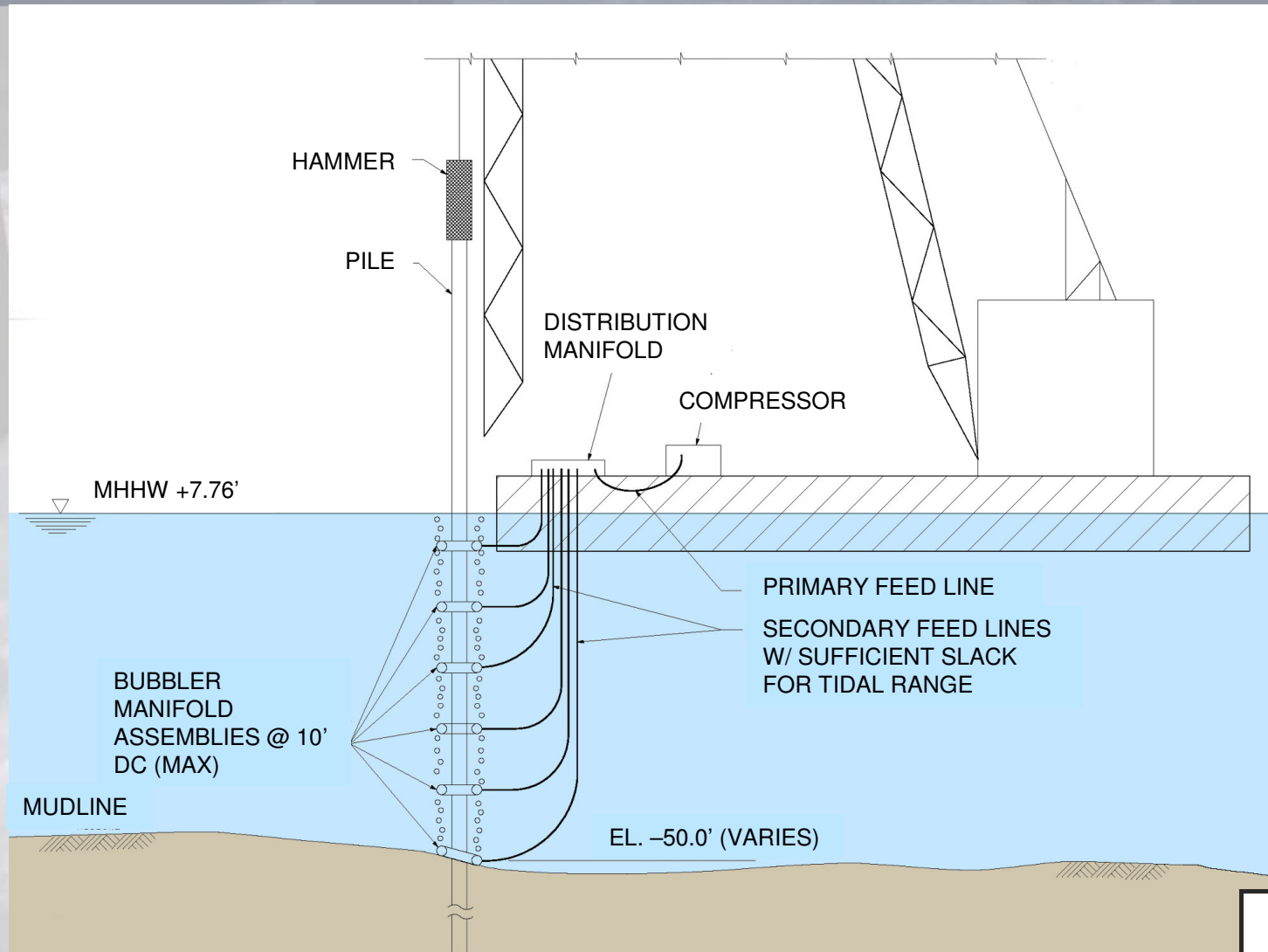
1. Primary requirement: piles shall be completely engulfed in bubbles during impact pile driving.
2. Bubble flux shall be uniformly distributed around the circumference of each bubbler and between bubblers at different depths.
3. Bubbler: 5' square or circle; 2" dia. steel pipe; 1/16" holes @ 3/4" centers.
4. The system shall provide a minimum bubble flux of 1 scfm (standard cubic foot per minute) delivered at 100 psi per hole in the bubblers.  
Bubbler = (4 sides x 5LF x 12 / .75 in/hole) x 1 scfm/hole = 320 scfm.
5. At minimum, provide bubblers at mudline and at 20 feet above mudline. Provide additional bubblers if currents disperse bubbles.
6. Compressor shall be oil-free.

# MUKILTEO TOWER REPAIR: Bubble Curtain Characteristics

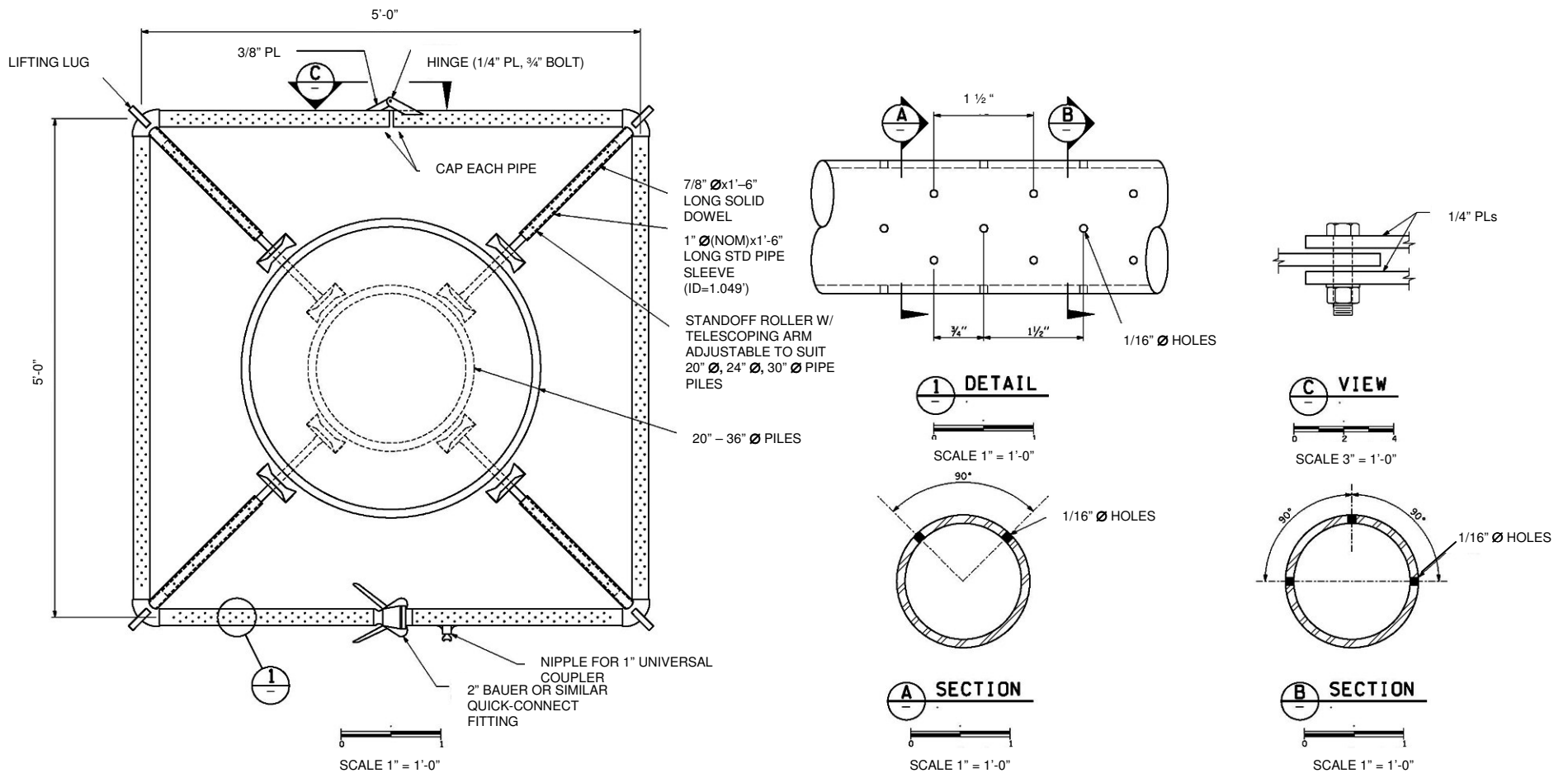
	<u>VANCOUVER</u> (2000)	<u>MUKILTEO</u> (2003)	<u>FRIDAY HARBOR</u> (2004)
<u>BUBBLER</u>			
SPACING (FT)	35	20	10
<u>HOLE</u>			
SIZE (INCH)	1/16	1/16	1/16
SPACING (INCH)	3/4	3/4	5 PER 1-1/2
HOLES/LF	16	16	40
<u>AIR VOLUME</u>	<u>CFM</u>	<u>SCFM</u>	<u>SCFM</u>
PER HOLE	1.04	1	0.4
SPACING (INCH)	16.7	16	16
HOLES/LF	?	320	320



# Friday Harbor Bubble Curtain

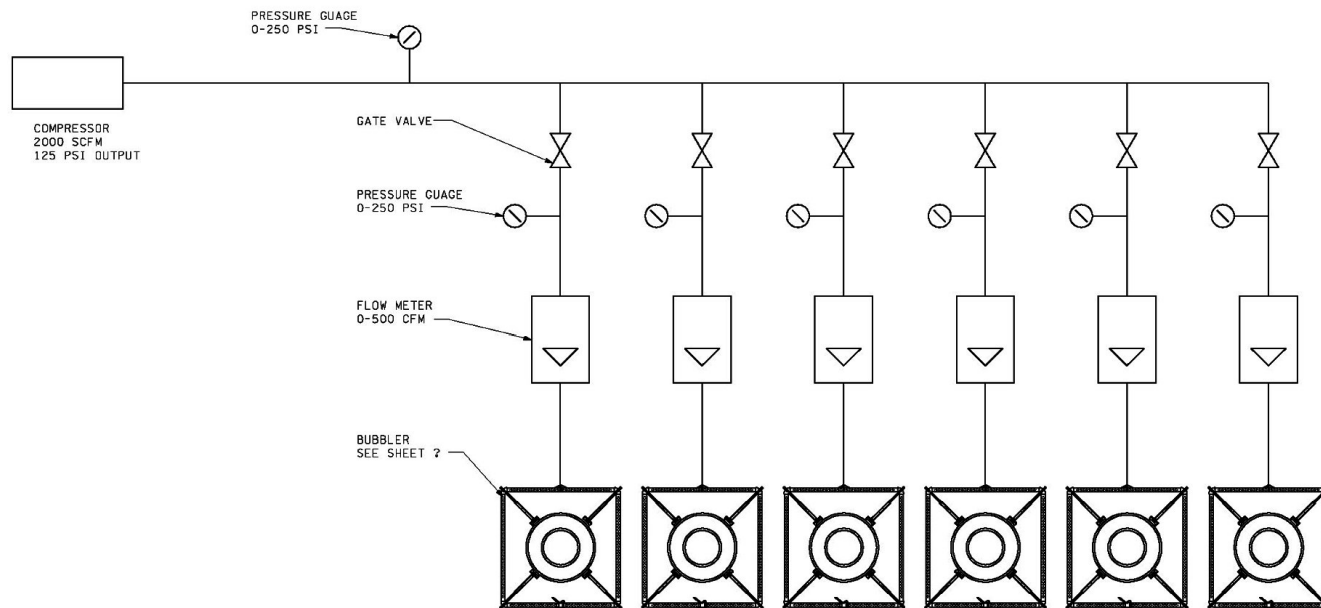


# Friday Harbor Bubble Curtain



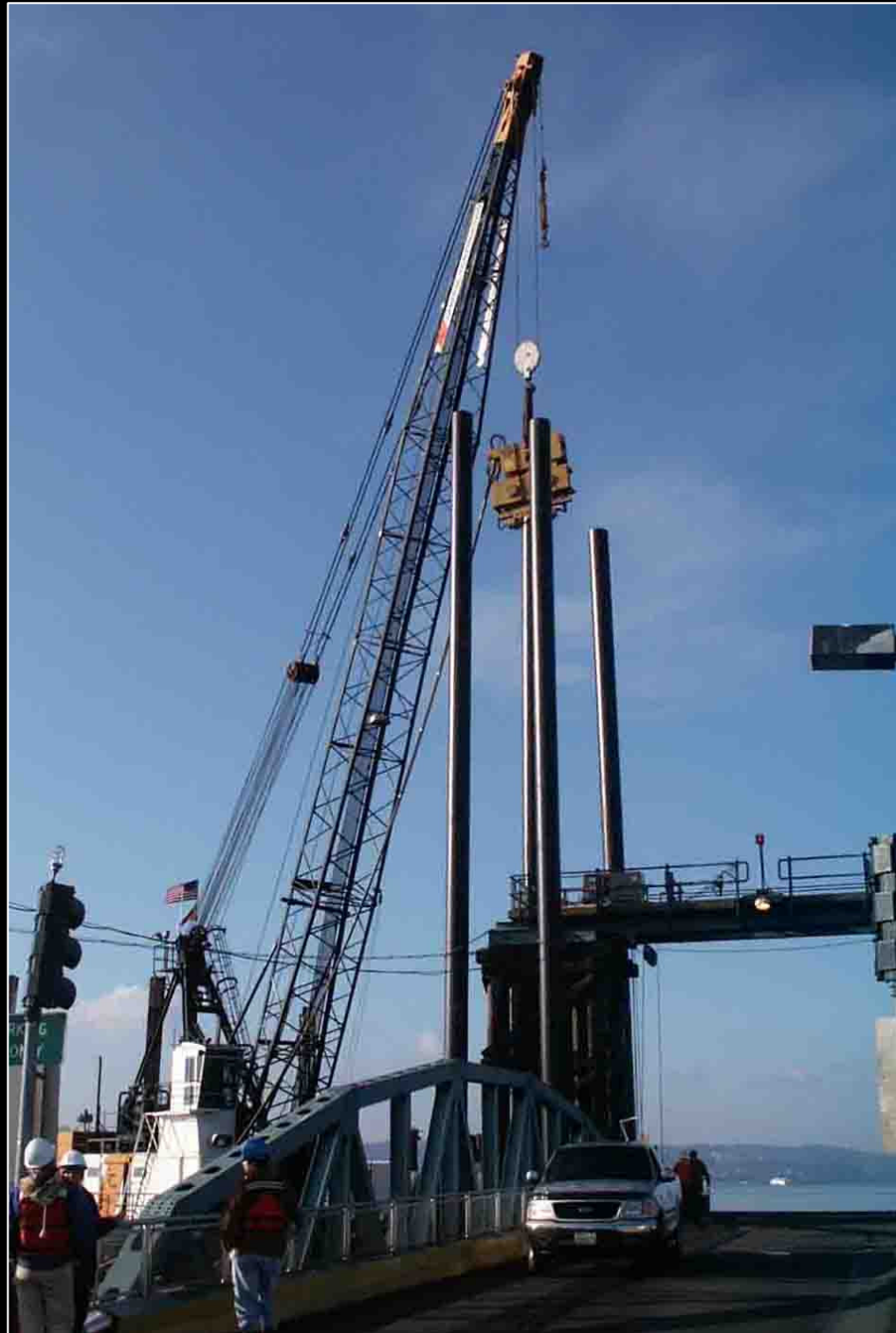


# Friday Harbor Bubble Curtain



**BUBBLE CURTAIN SCHEMATIC DIAGRAM**  
NO SCALE

BUBBLE CURTAIN DESIGN ASSUMPTIONS				
BUBBLER	ELEV	MAXIMUM WATER DEPTH (FT)	APPROX HYDROSTATIC PRESSURE (PSI)	REQD MIN FLOW VOLUME (CFM)
N/A	+11 (±) (HIGHEST TIDE)	0	0	-
1	0 (MLLW)	11	5.0	320
2	-10	21	9.5	320
3	-20	31	14.0	320
4	-30	41	18.5	320
5	-40	51	23.0	320
6	-50 (GROUNDLINE)	61	27.5	320





















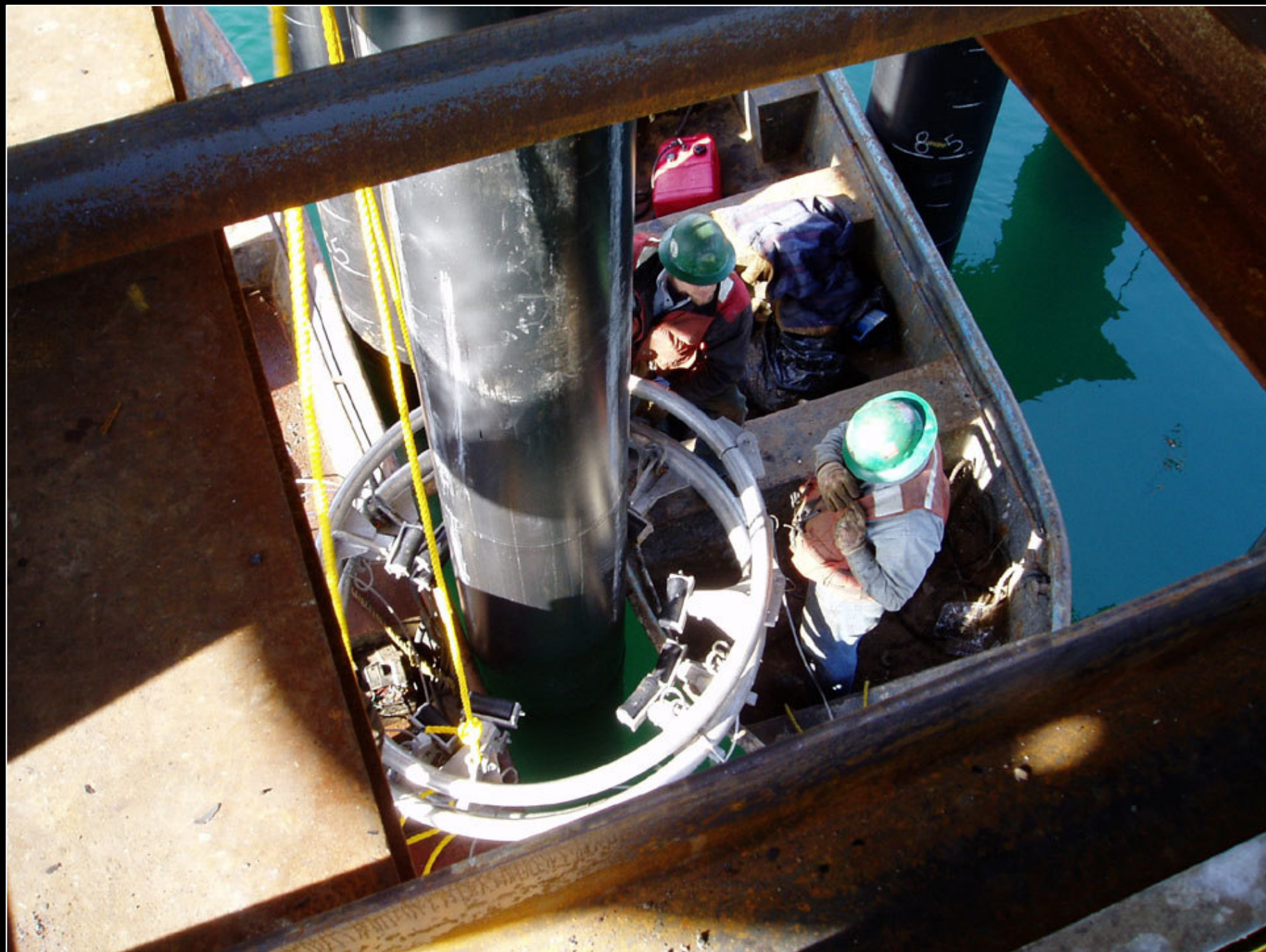




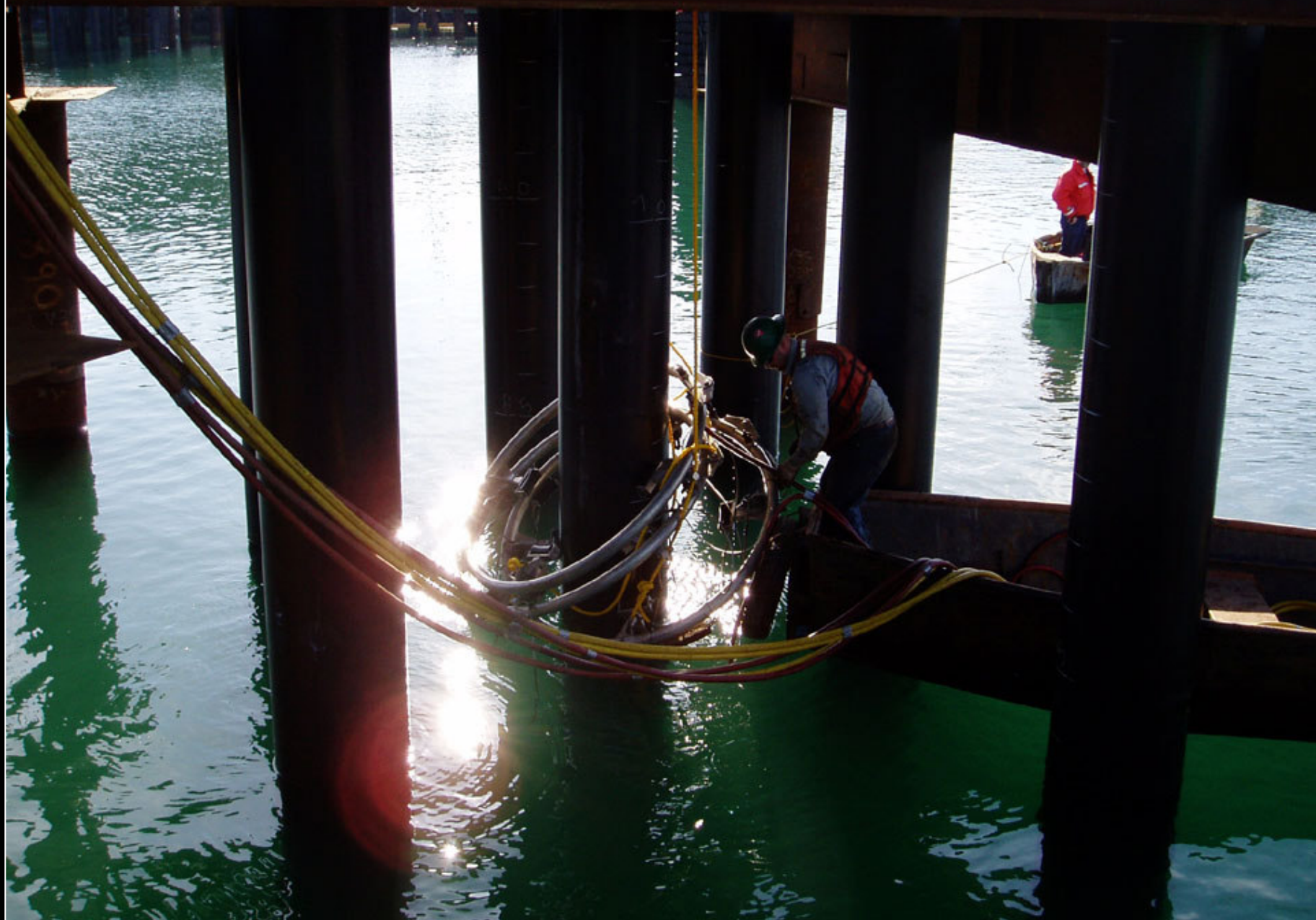








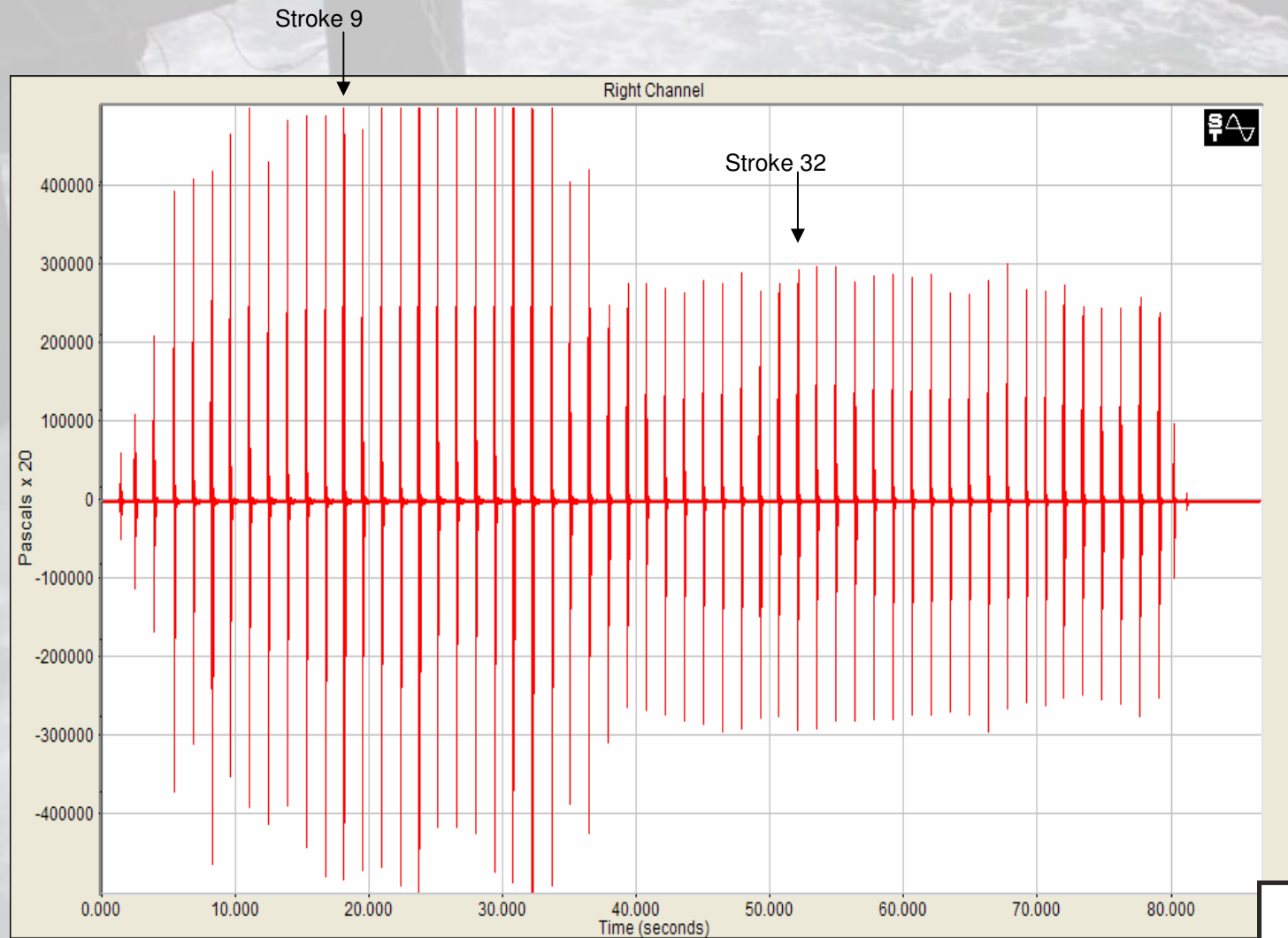






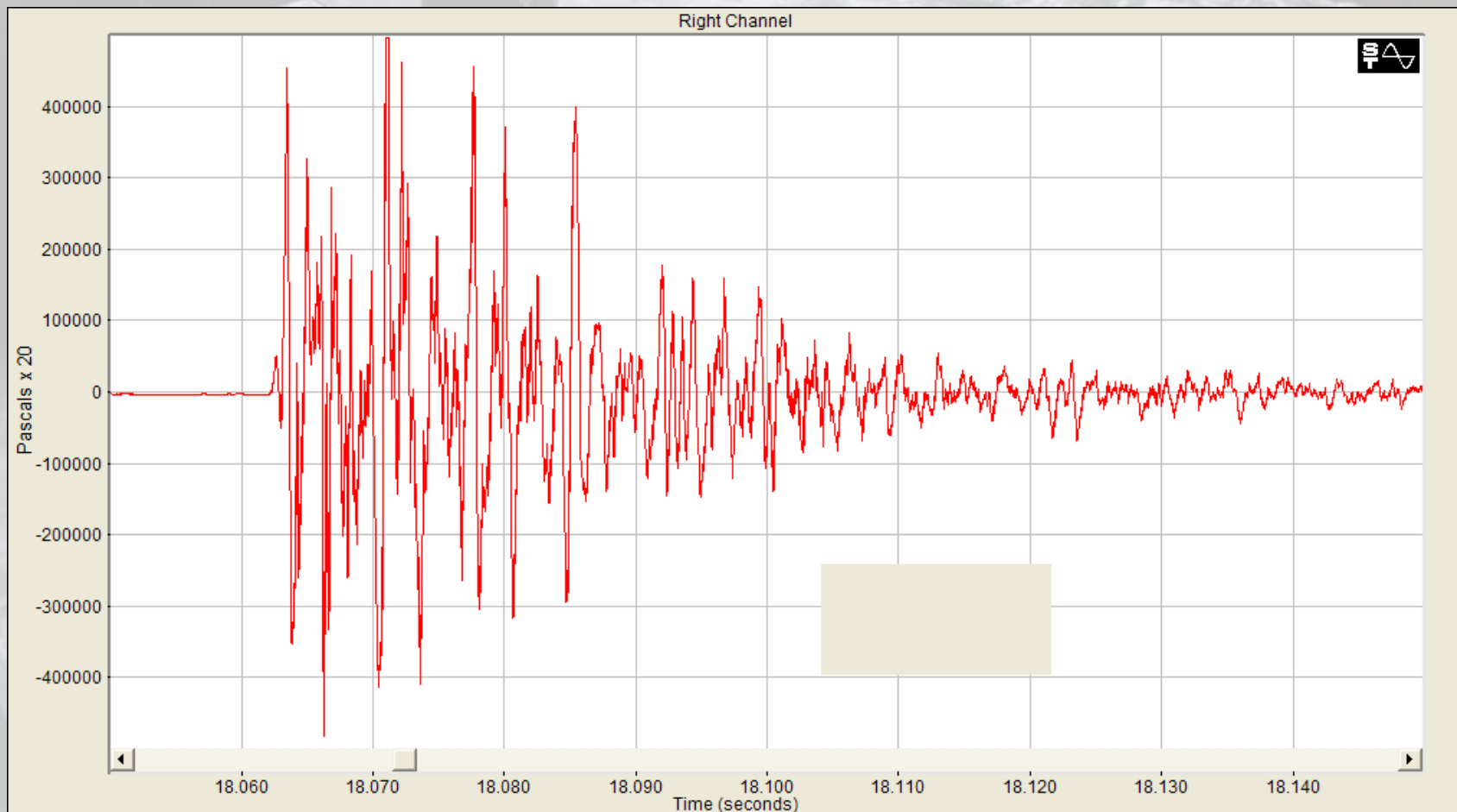


# MUKILTEO TOWER REPAIR: Pile R6 Acoustic Pressures



# MUKILTEO TOWER REPAIR: Pulse Time Series

02/07/2003 11:10 AM LOCAL

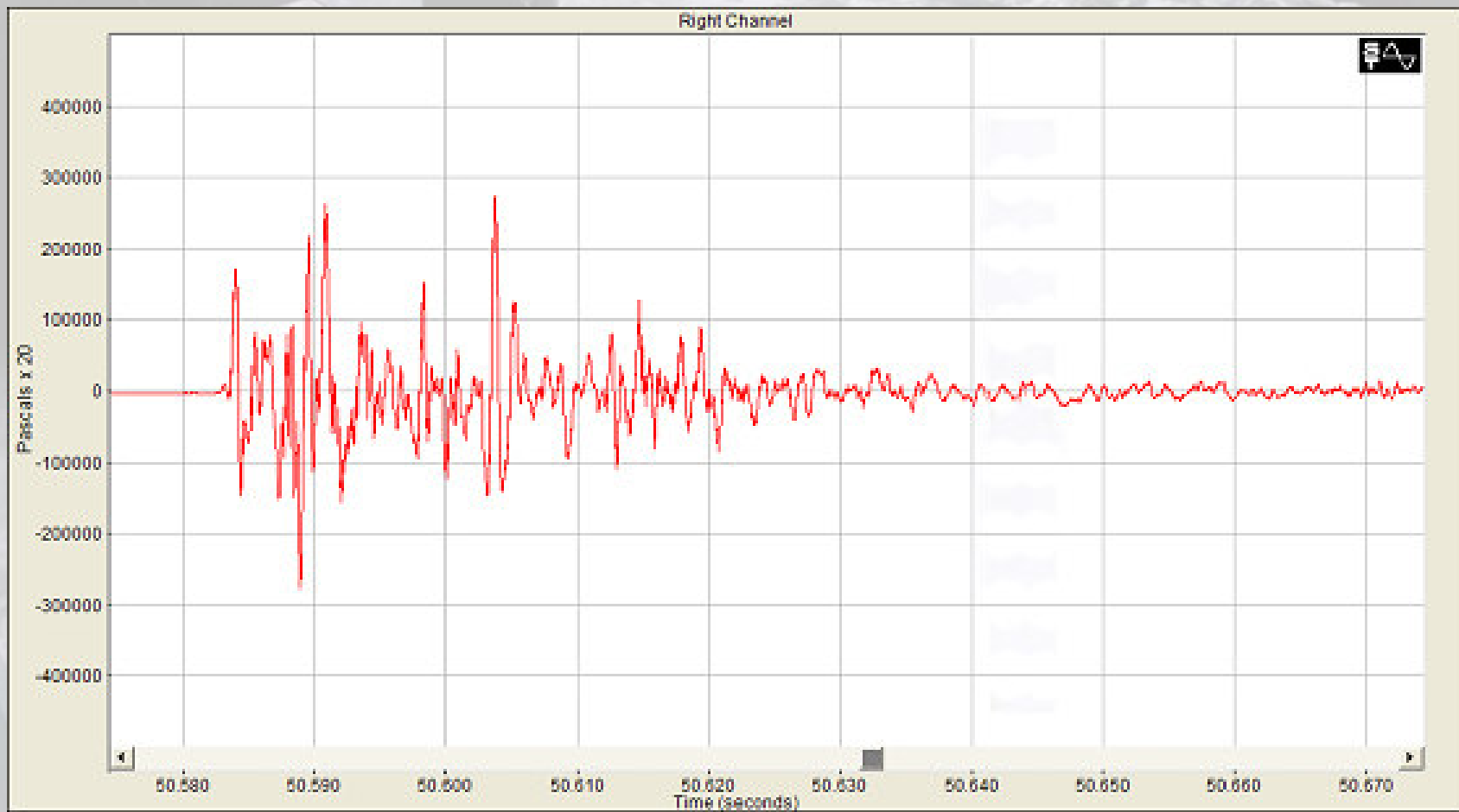


Stroke 9 - Bubble Curtain: **OFF**



# MUKILTEO TOWER REPAIR: Pulse Time Series

02/07/2003 11:10 AM LOCAL



Stroke 32 - Bubble Curtain: **ON**

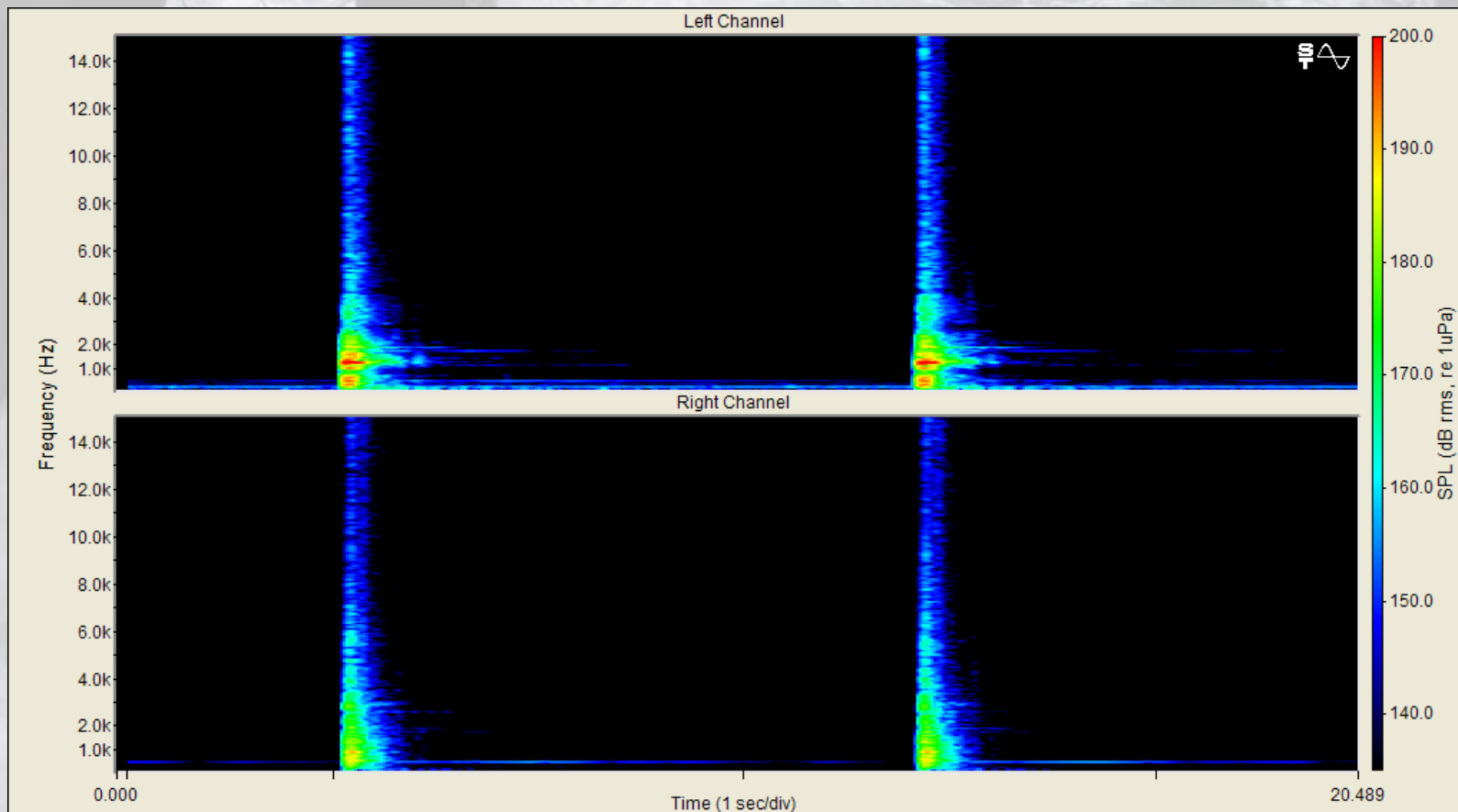
# MUKILTEO TOWER REPAIR: Pile R6 Spectrogram

Stroke 9

Stroke 10

**Left Channel:**  
Near source @ ~ 1 to 2 meters

**Right Channel:**  
Distant @ ~ 10 meters

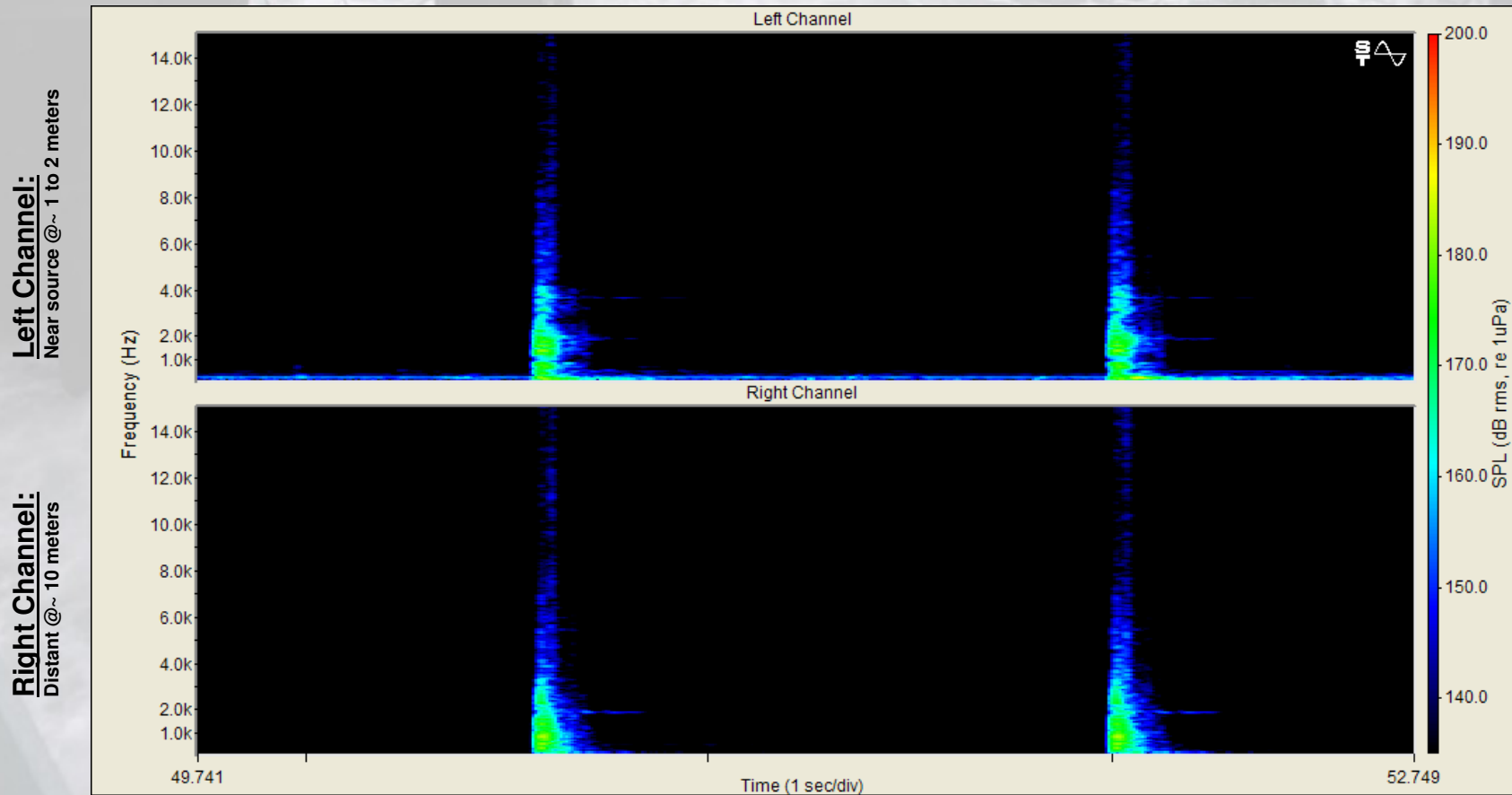


Stroke 9 & 10 - Bubble Curtain: **OFF**

# MUKILTEO TOWER REPAIR: Pile R6 Spectrogram

Stroke 32

Stroke 33



Stroke 9 & 10 - Bubble Curtain: **ON\***



\*Bubble Curtain operating at approximately 200 cfm, lower sparger ring only





# Cost

## Friday Harbor Bubble Curtain Bid Results

Engineer's Estimate	Low Bidder	2nd	3rd	4th	5th	Average Bid
\$ 70,000	\$ 73,000	\$120,000	\$ 55,000	\$ 51,000	\$ 80,000	\$ 75,800

- Contractor's line item bids may not reflect total cost impact.
- Pile driving unit price bid items may be inflated to reflect anticipated loss of productivity.
- Inflated pile driving unit costs are paid even if bubble curtain is not deployed.

# Lessons Learned

Unconfined bubble curtains are somewhat effective at reducing the transmission of pile-driving-generated sound pressures through water.

No data exists to demonstrate whether harm to fish is reduced when bubble curtains are used.

Bubble curtains are difficult and expensive to deploy.

Bubble curtains slow production of pile driving.

# Conclusion

Bubble curtains are not cost effective when used during the in-water construction season (July through February) because:

- There are few if any fish present during this time period.
- Reduction in harm to fish has not been demonstrated.



# Conclusion

Bubble curtains are not cost effective when used during the in-water construction season (July through February) because:

- There are few if any fish present during this time period.
- Reduction in harm to fish has not been demonstrated.

Bubble curtains will be cost effective when:

- They are shown to be effective at reducing harm to fish, AND
- Their use allows in-water construction to occur during the construction moratorium (fish window).

